

A Study on Foreign Drivers' Deceleration Behavior and Traffic Accident Risk in Japanese Popular Sightseeing Region

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Abstract: As the number of foreign rental car drivers increases in Japan, the safety measures for foreign drivers become essential. This study aims to identify the characteristics of deceleration behavior as a risky driving behavior. Besides, the Hazard-Accident Correspondence (HAC) model, which represents a relationship between the number of accidents and the number of deceleration occurrence, was estimated. The results show that foreign drivers tend to brake suddenly outside DID especially in the single road section compared to Japanese drivers. Additionally, the rate of deceleration occurrence at the intersection becomes large as the threshold of deceleration increases. However, there is a more remarkable tendency among foreigners than that among Japanese. HAC model shows that the number of deceleration occurrence can be used as a safety index, and it also implies that a complex intersection and the signalized intersection would be a hazard for foreign drivers.

Keywords: Road traffic safety, Foreign drivers, Rental car, Deceleration, Accident risk

1. INTRODUCTION

Recently the number of foreign tourists in Japan has increased by 20 million from 2007 to 2017. At the same time, the usage of a rental car by foreign tourists also has increased because of the usefulness of a rental car. For instance, in Hokkaido and Okinawa, which are one of the most popular sightseeing regions in Japan and said not to be covered by enough public transportation network, the number of cars rented out to foreigners in 2015 increased by about 1.7 times as compared to that in 2014. Consequently, the number of traffic accidents related to foreign rental car drivers would be getting higher as the usage of the rental car is getting higher. As a matter of facts, the number of injury and fatal accidents by foreign visitors who rent a car in Japan is increasing from 53 crashes in 2013 to 188 crashes in 2017 (Cabinet Office, Government of Japan, 2017). Besides, the number of foreign visitors is expected to grow continuously because of upcoming big events such as the Tokyo Olympics and Paralympics in 2020 and Osaka-Kansai Expo in 2025, and the number of foreign rental car drivers would also increase accordingly. Hence, the safety measures for foreign drivers have become essential. Against these backgrounds, this paper aims to identify the hazards of foreign rental car drivers to suggest effective safety measures.

Bone and Mowen (2006) identified a set of personality traits predictive of aggressive and distracted driving propensity as a hierarchical model framework. This study revealed four hierarchies, i.e., elemental, compound, situational, and surface traits affecting driving

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propensity. Elemental traits arise from genetics and early learning history while compound traits result from culture, sub-culture, the learning history of the individual. This study implies that a foreign driver has a different risky driving propensity from that of local drivers and it is different in the nationality because a foreign driver has each background.

To prove the different propensity in nationality, Yannis *et al.* (2007) investigated the relative accident fault risk distribution among different driver nationality categories in Greece. As a result, they revealed that the most significant effect on accident risk rises from the presence of foreign drivers at intersections. Kim and Zhang (2017) conducted the preference survey of foreign drivers to investigate the relationship between drivers' characteristics and their preference for attributes related to the risk of driving in New Zealand. They suggested that an unfamiliar road environment such as roundabout system brings confusion to foreign drivers. Additionally, Yoh *et al.* (2017) found the characteristics of foreign drivers using traffic accident and violation statistics in Japan. These studies showed the specific risk of foreign drivers and examined the accidents which are the results of the behaviors, and preference which is a part of the causes of behaviors by analyzing the statistics and questionnaire survey. However, the relationship between nationality and actual driving behavior were not examined though there are a lot of previous studies on driving behaviors of domestic drivers or drivers in a country/region. Therefore this study focuses on the difference of risky driving behaviors in drivers' nationality, or drivers' home country/region especially using probe car data.

Recently probe car data were used to model the travel time (e.g., Uno *et al.*, 2009) and traffic incident detection (e.g., Cheu *et al.*, 2004), and so on. Also, there are many studies related to risky driving behavior using probe car data. Odaka *et al.* (2018) analyzed the accident risk of the residential road using ETC2.0 data, which is a Japanese ITS system including correction of probe vehicle data. Kikuchi *et al.* (2012) proposed new evaluation indices called the Hiyari-Hat (incident) indices such as deceleration intensity which is estimated using probe data. Oyanagi *et al.* (2014) used sudden braking data as a safety index of the intersection. The sudden braking and the deceleration intensity were regarded as one of the safety indices influenced by risky driving behavior. Therefore these indices were used to identify the characteristics of foreigners' driving behaviors in this study.

Foreign drivers tend to be confused when they drive in an unfamiliar road environment (Kim and Zhang, 2017). Beside, Yannis *et al.* (2007) and Yoh *et al.* (2017) concluded foreign drivers have a higher risk at an intersection. This study firstly aims to identify the characteristics of where foreign drivers tend to decelerate/slowdown suddenly and then reveal the hazardous factor of road environment by estimating the accident risk model.

2. METHODOLOGY

2.1 Data Collection

2.1.1 Subject area

In this study, we selected Hokkaido region in Japan as a subject area. Figure 1 shows the number of foreign rental car drivers in 2014 and 2015 in Hokkaido-region. This figure represents that the number of foreign rental car drivers is increasing mainly among Korean, Taiwanese, Hong Kong, and other Asian drivers. According to the Foreign Flow Data (The MLIT of Japan, 2016), 6.4% of foreign tourists who entered Japan through international airports in Hokkaido region rent a car. This high ratio of rental cars usage is the second largest

value next to that of Okinawa prefecture. As mentioned above, Hokkaido-region is selected as the subject area, which many foreign tourists visit and is expected still more foreign tourists visit.

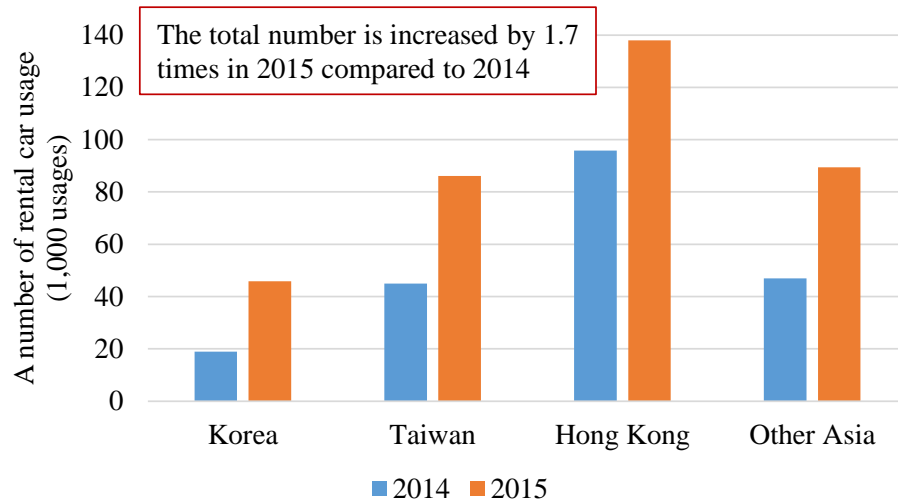


Figure 1. The increasing number of rental car usage in Hokkaido region

2.1.2 Deceleration data

ETC2.0 probe car data used in this study acquired by DENSO Corporation in the framework of the field operational test to support for logistics using ETC2.0 on-board unit and DSRC roadside unit, which were held by The National Institute for Land and Infrastructure Management (Negishi et al., 2016).

Figure 2 shows the detailed information of the data. The data was collected from rental cars were rented out at a rental car company locating near the most significant international airport in Hokkaido-region called the New Chitose Airport from August 1 to October 31, 2016. In the target period, snow accumulation was not observed, and the road surface was not in slippery condition. The collected ETC2.0 probe car data includes the intensity of deceleration, the degree of speed, latitude, and longitude when sudden braking with over 0.25G degree of deceleration occurs, and the driver's home country/region. The number of total deceleration data is 5,109. 2,600 of which are attributed to Japanese drivers, the rest by foreigners. Figure 2 shows the composition ratio of the data by country/region. Compared with the composition ratio of foreign rental car drivers in Hokkaido, Hong Kong, Korea, and other Asian regions are ranked higher, although Taiwanese is small, composition ratio of the sample is in line with the reality.

ETC2.0 Car Probe Data used in this analysis

- Term : 1st Aug.~31st Oct. 2016 (no snow among this term)
- Object Drivers : Drivers who rent a car near the New Chitose Airport
- Contents : Sudden brake event with more than 0.25G- deceleration, Magnitude of speed, Location, Drivers nationality
- Number: Foreigner 2,509 events, Japanese 2,600 events

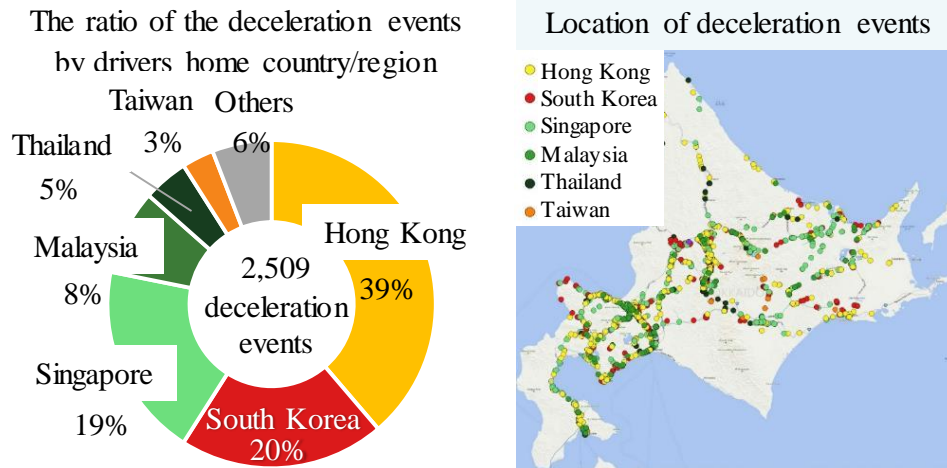


Figure 2. The corrected data used in this study

2.1.3 Accident data

Hokkaido local police agency provided us traffic accident data. The contents are on injury and fatal accidents caused by foreign rental car drivers who visit Japan for sightseeing purposes. According to this data, in Hokkaido, 102 injury and fatal accidents occurred in the past ten years, including 55 crashes by Chinese drivers, 19 crashes by Taiwanese drivers, and 15 crashes by South-Korean drivers. Since China (mainland) doesn't participate in the 1949 Geneva Convention, driving with Chinese drivers' license is not permitted in Japan. Therefore, a Chinese driver in this study is regarded as a Hong Kong driver who is recorded as Chinese by Japanese police. From now on China in this data is referred to as Hong Kong, which ratified the 1949 Geneva Convention.

2.2 Method

The location where the event occurs were added to deceleration data using Digital Road Map created by Japan Digital Road Map Association and National Land Numerical Information provided by MLIT.

Firstly, data of the event occurs on the highway were removed. As a result, 430 deceleration event data including 230 events by foreign drivers and 200 events by Japanese drivers were removed.

Secondary, it was judged whether or not the event point is within DID (Densely Inhabited District: population density is 4000 people/km² or more) using National Land Numerical Information (DID population concentration data). Especially in Hokkaido, the difference in the traffic volume of vehicles, bicycles, and pedestrians, the number of

intersections per road extension, and the number of signals is considered to be remarkable in DID and outside DID. In other words, the surrounding environment should strongly influence driving behaviors in the DID, and by contrast, it should do relatively small outside the DID.

Finally, it was judged whether or not the event point occurred within and around an intersection. The interior and its vicinity of an intersection were defined as being within 30 meters from the center of the intersection node. The Hubeny's distance formula (Hubeny, 1959) was used when calculating the distance.

After creating the data set for analyses, the composition ratio of location recorded when a deceleration event occurs were compared between foreign drivers and Japanese drivers using a chi-square test of independence. Here, three sets of chi-square tests were applied to examine the relationships between drivers' home country/region and the aggregated number of deceleration event by location categories: 1) whether within DID or outside DID, 2) whether within and around an intersection or a single road section within DID and 3) whether within and around an intersection or a single road section outside DID. The classification of drivers' home country/region is as shown in Table 1.

Table 1 The classification of drivers' home country/region

Name	Explanation	Concrete countries/regions
Foreigner	-	All the countries/regions other than Japan
LHT	Left-hand traffic countries/regions	U.K., India, Australia, Singapore, Macau and Hong Kong
RHT	Right-hand traffic countries/regions	U.S., Italy, Netherlands, Germany, French, Thailand, Chile, Malaysia, Taiwan and South Korea
Hong Kong	The most number of rent-a-car usage in Hokkaido region	Hong Kong
South Korea	The second most number of rental car usage in Hokkaido region	South Korea
South East Asia	The usages are recently expanded all over Japan	Thailand and Malaysia

In the previous studies (Yannis *et al.*, 2007; Yoh *et al.*, 2017), the accident risk of foreign drivers was remarkable at the intersection. Thereby in this study, we specify the environment of intersection which raises the accident risk of foreign drivers in addition to examine the relationship between deceleration and accident. To reveal this relationship, the Poisson regression model estimating the number of injury and fatal accidents in an intersection (Equation 1). The estimated model is called HAC model: Hazard-Accident Correspondence model.

$$y = \exp(\beta_0 + \beta x + \sum \beta_k d_k) \quad (1)$$

where,

- y : number of injury and fatal accidents,
- x : number of deceleration event,
- d_k : dummy parameters of intersection type, and
- β_0, β, β_k : unknown parameters.

As stated before, the characteristics of the road environment are much different from inside and outside DID in Hokkaido. In this case, we analyze limited area: within the DID,

especially the intersection in Sapporo city, which is the largest city in Hokkaido-region. Large intersection, complex intersection, and signalized intersection were adopted as explanatory variables. The definition of each value is as shown in Table 2.

Table 2. The explanatory variables

Name of variables	Definition
Large intersection	All the roads connecting to an intersection are more than 13m wide.
Complex intersection	More than five roads are connecting an intersection.
Signalized intersection	All the roads connecting to an intersection are more than 5.5m wide. And at least an arterial roads connect to an intersection.

3. RESULT

3.1 Comparison of Composition Ratios of the Deceleration-Occurrence-Location

Table 3 shows the number of deceleration occurrences within DID and outside DID of each drivers' home country/region. The results of chi-square tests applying to drivers of each country/region and Japanese drivers are shown as asterisks. As a result, the significant differences are found in the comparison between the ratio of Japanese drivers and that of whole foreign drivers ($X^2 = 6.81$, $p < 0.01$) and the drivers of RHT countries ($X^2 = 6.16$, $p < 0.05$). Also, the results implied that whole foreigners and RHT countries drivers tend to brake suddenly outside the DID compared with Japanese drivers.

Table 3. The number of deceleration occurrences within DID and outside DID

Numbers Ratio	Japan	Whole foreigner	LHT	RHT	Hong Kong	South Korea	South-east Asia
General road	2400	2279	1410	869	863	459	288
Inside DID	1022 42.60%	885 38.80%	557 39.50%	328 37.70%	346 40.10%	180 39.20%	106 36.80%
Outside DID	1378 57.40%	1394 61.20%	853 60.50%	541 62.30%	517 59.90%	279 60.80%	182 63.20%
X^2	-	6.18**	3.47	6.16*	1.62	1.79	3.52

** Significant at 1% level; * Significant at 5% level.

Table 4 shows the number of deceleration occurrences at an intersection and a single road section in DID. The independence tests were also carried out. However, there was no statistically significant difference.

Table 4. The number of deceleration occurrences within DID

Numbers Ratio	Japan	Whole foreigner	LHT	RHT	Hong Kong	South Korea	South-east Asia
In or around an intersection	540 52.80%	469 53.00%	293 52.60%	176 53.70%	184 53.20%	92 51.10%	65 61.30%
A single road section	482 47.20%	416 47.00%	264 47.40%	152 46.30%	162 46.80%	88 48.90%	41 38.70%
X^2	-	0.00	0.01	0.07	0.01	0.18	2.78

** Significant at 1% level; * Significant at 5% level.

On the other hand, Table 5 shows the number of deceleration occurrences at an intersection and a single road section outside DID. As a result of independence tests, a significant relationship between the composition ration of whole foreign drives and that of Japanese drivers was found ($X^2=4.76$, $p < 0.05$). The result also implied that foreign drivers tend to brake suddenly within and around an intersection outside DID compared with Japanese drivers.

Table 5. The number of deceleration occurrences outside DID

Numbers Ratio	Japan	Whole foreigner	LHT	RHT	Hong Kong	South Korea	South -east Asia
In or around an intersection	499 36.20%	450** 32.30%	278 32.60%	171 31.80%	165 31.90%	86 30.80%	61 33.50%
A single road section	879 63.80%	944** 67.70%	575 67.40%	369 68.20%	352 68.10%	193 69.20%	121 66.50%
X2	-	4.76**	3.04	3.53	3.05	2.95	0.51

** Significant at 1% level; * Significant at 5% level.

3.2 Comparison by Intensity of Deceleration

At section 3.1, a deceleration event represents the event with 0.25G or more degree of deceleration. This section focused on the intensity of deceleration. By increasing the threshold, the shifts in each ratio were examined.

Figure 3 expresses the ratio of deceleration occurrence at and around the intersection in the DID. It can be seen from this figure that as the threshold is raised, the occurrence ratio of deceleration within the intersection is increased. By expanding the deceleration threshold from 0.25 G to 0.45 G, the rate of rapid deceleration by Japanese drivers at the intersection increased by 17.4% from 52.8% to 70.2%, whereas that by foreigners increased by 26.4% from 53.0% to 79.4%. Compared to Japanese drivers, foreigners tend to perform sudden braking with massive deceleration at an intersection in DID, suggesting a higher risk of accidents at an intersection than Japanese drivers.

On the other hand, the deceleration occurrence ratio at and around the intersection outside DID is as shown in Figure 4. As the threshold is raised, the rate of deceleration occurrence within the intersection is increasing as in DID. Additionally, the increase in deceleration occurrence ratio within the intersection due to raising the threshold from 0.25 G to 0.45 G is 11.8% for Japanese drivers and 19.6% for foreigners. However, the ratio at 0.45-G-threshold of Hong Kong and Korean drivers are almost the same as that of Japanese drivers. Different from the result on inside DID, the result implied that the location of deceleration event is comparatively the same among foreign drivers and Japanese drivers.

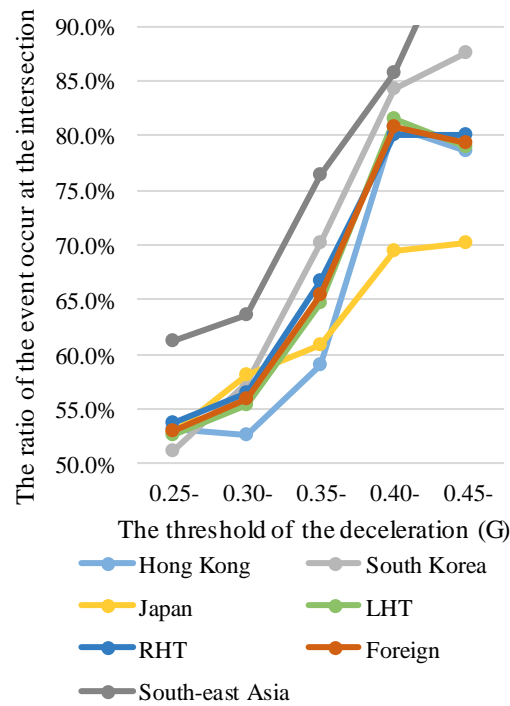


Figure 3. The ratio of the event occurs at the intersection inside DID

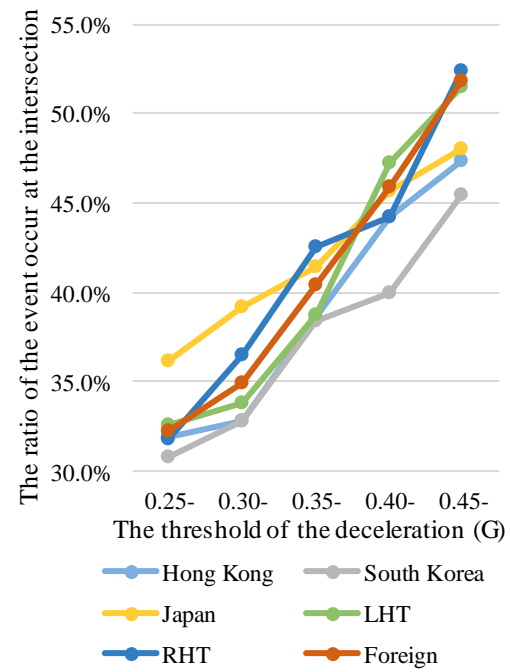


Figure 4. The ratio of the event occurs at the intersection outside DID

3.3 Analysis of the Traffic Accident Factors at an Intersection in DID

To identify the risk factor, the HAC model was estimated by the maximum likelihood method. On the process of estimation, the stepwise method was used to minimize the AIC of the model and select the explanatory valuables. As a result, the large intersection valuable was removed from HAC model. Table 6 shows the result of the estimation. Chi-square value represented 0.1% significant. Besides, all selected explanatory variables were significant. The coefficients of complex intersection dummy and signal intersection dummy take positive values, respectively, which indicates that these road environments can cause accidents related to foreign drivers.

Table 6. The result of estimation of the HAC model

Explanatory	Coefficient	St. deviation	Z-value
Constant	-7.69	0.32	-24.32***
Complex intersection dummy	3.21	0.8	4.01***
Signalized intersection dummy	1.41	0.47	3.02**
Number of deceleration events	0.86	0.2	4.38***

*** Significant at 0.1% level; ** Significant at 1% level; * Significant at 5% level.

4. CONCLUSION

In this study, we analyzed the deceleration behavior and accident risk of foreign rental car drivers using ETC 2.0 probe data and accident data in Hokkaido.

First, the composition ratio of location recorded when a deceleration event occurs were

compared between foreign drivers and Japanese. The result shows foreign drivers tend to slow down suddenly outside DID especially in the single road section. The roads outside DID in Hokkaido are wide enough to accommodate snow in winter and have relatively few road traffic, intersections, signals, and other road furniture. The road situation would allow drivers to drive freely. Under this condition, foreign drivers could face hazardous situations more often than Japanese drivers.

Next, we analyzed the relationship between the magnitude of the deceleration and the deceleration occurrence ratio on intersections and single road sections. Regardless of drivers' country/region, the rate of deceleration occurrence at intersection becomes large as the threshold of deceleration increases. However, there is a more remarkable tendency among foreigners than that among Japanese, which implies that foreign drivers have a higher risk at an intersection especially in DID than Japanese have. This result is almost the same as a result of previous studies.

Furthermore, to identify specific accident risk factors of foreign drivers at the intersection, HAC model, which shows a relationship between the number of accidents, and the number of deceleration and the type of intersection, was estimated. As a result, the complex intersection (more-than-5-road-connecting intersection) dummy, signal intersection dummy, and the number of deceleration occurrence were selected as significant positive explanatory variables. The complexity of the intersection and signalized intersection increased accident risk. That could be because the difference in the rules of driving at the intersection and shape, location, arrangement of the traffic right are confusing foreign drivers. Additionally, the result also showed a significant relationship between accidents and deceleration. Through this, the probe data on deceleration would be an effective index of foreign drivers' safety.

As described above, in this research, we have characterized the driving behavior and accident risk factors of foreign drivers. As a result, although there were a few clear differences among foreign drivers, the difference between foreign driver and Japanese driver was revealed.

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